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Spatial interaction between spiders and prey insects: horizontal and vertical distribution in a paddy field

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Abstract — We surveyed the populations of spiders and their prey insects in a paddy field under sustainable cultivation in Aso, Kumamoto Prefecture in 2001 and 2003. Dominant species of spiders were *Pardosa pseudoannulata, Tetragnatha* sp. (certainly *T. maxillosa*) and *Clubiona kurilensis* and dominant prey insects included a non-pest, i.e. chironomids, and rice pests, i.e. *Sogatella furcifera* and *Nephotettix cincticeps*. We investigated the spatial distribution of the dominant species involving the vertical distribution on rice plants and the horizontal distribution within a paddy field. *Sogatella furcifera* and *C. kurilensis* were mostly located at lower parts of rice plants, 0–10 cm high, and sometimes at the upper parts. *Pardosa pseudoannulata* inhabited significantly lower parts, 0 and 0–5 cm, than the two species. On the other hand, *N. cincticeps* was observed from lower to upper parts. We surveyed the number of spiders and prey insects in 26 quadrats of 1 ×1 m and analyzed the degree of spatial overlapping between them using the Iwao's (1977) ω index. High values of ω were obtained between all spiders and chironomids and between *C. kurilensis* and *S. furcifera*. These results suggest that chironomids are important prey for spiders and *C. kurilensis* is an effective predator of rice planthoppers though this spider has not been regarded as an important predator.

Key words — spatial overlapping, vertical distribution, Chironomidae, rice planthoppers, *Pardosa pseudoannulata*, *Clubiona kurilensis*, Tetragnathidae

Introduction

Spiders are one of the most abundant predators of insect pests in paddy fields (Kobayashi 1961; Kuno 1968; Kawahara et al. 1969; Hamamura 1969; Kenmore et al. 1984; Wada & Nik 1992; Sawada et al. 1993). Many authors suggest that spiders are important as biological control agents for insect pests of rice, especially planthoppers and leafhoppers, e.g. *Nephotettix cincticeps* and *Nilaparvata lugens* (Itô et al. 1962; Kawahara et al. 1971; Kiritani et al. 1972; Kenmore et al. 1984; Oraze & Grigarick 1989; Wada & Nik 1992; Tanaka et al. 2000). Fauna and the density of spiders, however, are affected by the management or farming systems of paddies (Hidaka 1990; Murata 1995). The density of spiders also depends on the availability of their prey including pest and non-pest insects. The non-pest insects may be important as an alternative prey to maintain the spider populations when the pest populations are at low density (Riechert 1984; Way & Heong 1994; Settle et al. 1996; Tanaka 2003). Several studies showed that polyphagous predators including spiders were more abundant in the paddy fields that afforded more alternative prey such as chilonomids than those affording fewer prey (Kobayashi 1975; Hidaka 1990; Murata 1995; Settle et al. 1996). There are, however, few works analyzing the interaction between the predators and the alternative prey.

To effectively utilize the spiders as biological control agents in paddies, we should understand the interaction between the spiders and their prey as well as the biology of them. Most of works concerning the interaction between predators and their prey of crop pests have dealt the mean densities of them. The density varies spatially and temporally. Hence, the spatial distributions of predators and prey within a field and the relationship between their distributions should be studied (Tanaka 1989). Vertical distributions on rice plants varied from species to species in the rice planthoppers and leafhoppers as well as horizontal distributions in a paddy field (Kuno 1968). In this study, we investigated the horizontal and vertical distributions of spiders and their prey insects in a paddy field and analyzed the spatial interaction between them.

Materials and Methods

Study field

This study was carried out in 2001 and 2003, in a rice paddy field (72 a) that was located at an elevation of 490 m in a rural area of Aso Town, Kumamoto Prefecture in the western Japan. This field has been under sustainable

Table 1. The management of the paddy field surveyed in 2001 and 2003.

Management	2001	2003
Rice cultivar	Koshihikari	Koshihikari
Besal fertilizer		
NPK＝15:13:15	40 kg/10 a	40 kg/10 a
Additional fertilizer		
NPK＝4:6:4	20 kg/10 a	20 kg/10 a
Ammonium sulfate	10 kg/10 a	20 kg/10 a
Date of transplanting	13 May	9 May
Date of harvesting	10 Sep.	17 Sep.
Planting density	18 hills/m^2	18 hills/m^2
Yield (hulled rice)	484 kg/10 a	450 kg/10 a
Pesticides	None	None

cultivation and applied with no insecticides, fungicides or herbicides since 1992. The study field was surrounded by the following farms: rice paddies under conventional cultivation on the north and south of it, a paddy field under organic cultivation on the east, and a fallow field and rice paddies on the west. The management of the study field is shown in Table 1. In 2001 and 2003, the field was planted with a rice cultivar, Koshihikari. No insecticides, fungicides or herbicides were applied in the study field and its surrounding fields throughout the study periods.

Density and spatial distribution of spiders and prey insects

We surveyed spiders and prey insects using three sampling methods: sweeping, hand collecting and direct counting. In both years, we surveyed the density of leafhoppers and planthoppers ca. every ten days from transplanting to harvesting by a sweeping method using an insect net of 42 cm in diameter. We set five quadrats of 1×1 m, four at periphery and one at the center of the field. Fifteen sweeps were undertaken per quadrat.

To know dominant species of spiders, we performed hand collecting in other five quadrats of 1×1 m. We caught spiders in a quadrat for 3 min. To investigate vertical distributions on rice plants（height from the paddy water surface）of spiders and prey insects, we carried out direct counting in three 1×1 m quadrats that were randomly set in the field. We observed the number of spiders and prey insects and their height on rice plants. The height was measured with a rule. We carried out these surveys every 1 hr from the sunrise to the sunset and could complete each observation in a quadrat within 3 min. We observed the following species or taxons: *Sogatella furcifera*, *N. cincticeps*, *Pardosa pseudoannulata* (Lycosidae), *Clubiona kurilensis* (Clubionidae), Tetragnathidae and Chironomidae that were shown to be abundant in this area by the previous papers (Murata & Nohara 1994; Murata 1995）or considered important as rice pests, predators or alternative prey. The hand collecting and direct counting were conducted ca. every two weeks from 2 June to 13 August 2001.

The survey in 2001 revealed the dominant species of spiders and prey insects in this field. To analyze the spatial distribution of them in detail, we conducted the direct counting on 6 June, 21 June and 26 July 2003 in 26 quadrats of 1×1 m that were set at random in the field. We observed the height of spiders and prey insects on rice plants with a rule. We conducted these surveys every 2 hr from the sunrise to the sunset and could complete each observation in a quadrat within 3 min.

Analysis of spatial distribution

We analyzed the spatial distribution patterns of spiders and prey insects using the Morisita's (1959) I_δ index. We also analyzed the spatial relationship between species using the index of interspecies spatial correlation, ω (Iwao 1977) that represents the degree of spatial overlapping between two species based on the interspecies mean crowding: $\omega = +1$ when the distributions of the two species completely overlap, $\omega = 0$ when they are independent, and $\omega = -1$ when they are completely exclusive. We calculated the I_δ and ω values using the number of each species or taxons in each of 26 quadrats that were obtained on three survey days in 2003.

Results

Seasonal fluctuations in populations of planthoppers and leafhoppers

Figure 1 shows seasonal fluctuations of hopper populations censused by the sweeping method, rainfall, and air temperatures in 2001 and 2003. The dominant species were *S. furcifera* and *N. cincticeps* in both years. We did not collect *N. lugens*. The number of *S. furcifera* collected was larger in 2003 than 2001. After late July, its number decreased in 2001 while it increased in 2003, which resulted in a great difference in populations between the two years. On the other hand, the number of *N. cincticeps* was larger in 2001 than 2003. After late August, its number increased in 2001 while it did not clearly increase in 2003.

Species composition of spiders and insects

A total of 26 spider species belonging to 9 families were caught by the hand collecting method in this field (Table 2). Dominant species were *Tetragnatha* sp.1 and *P. pseudoannulata* in this survey. Three spider guilds, i.e. orb web, space web and hunting spiders, were abundant in this field. Of the orb web spiders, only Tetragnathidae including *Tetragnatha* spp., *T. maxillosa*, and *Leucauge subgemmea* were found. All the individuals of *Tetragnatha* sp.1 were juveniles and the large nymphs of them had morphological characteristics of *T. maxillosa*. Thus, most of them certainly belong to *T. maxillosa*. Of the hunting spiders, *P. pseudoannulata* was most dominant and other two *Pardosa* species, pisaulids, and clubionids were rather abundant. *Clubiona* sp.1 that were juveniles probably belong to *C. kurilensis*. Thus, *C. kurilensis* was the third dominant spider. Space web spiders included several species of Theridiidae and Linyphiidae.

Table 3 shows species of insects that we found by direct counting in the study field. Dominant predacious insects were *Gerris lacustris latiabdominis* (Gerridae) and

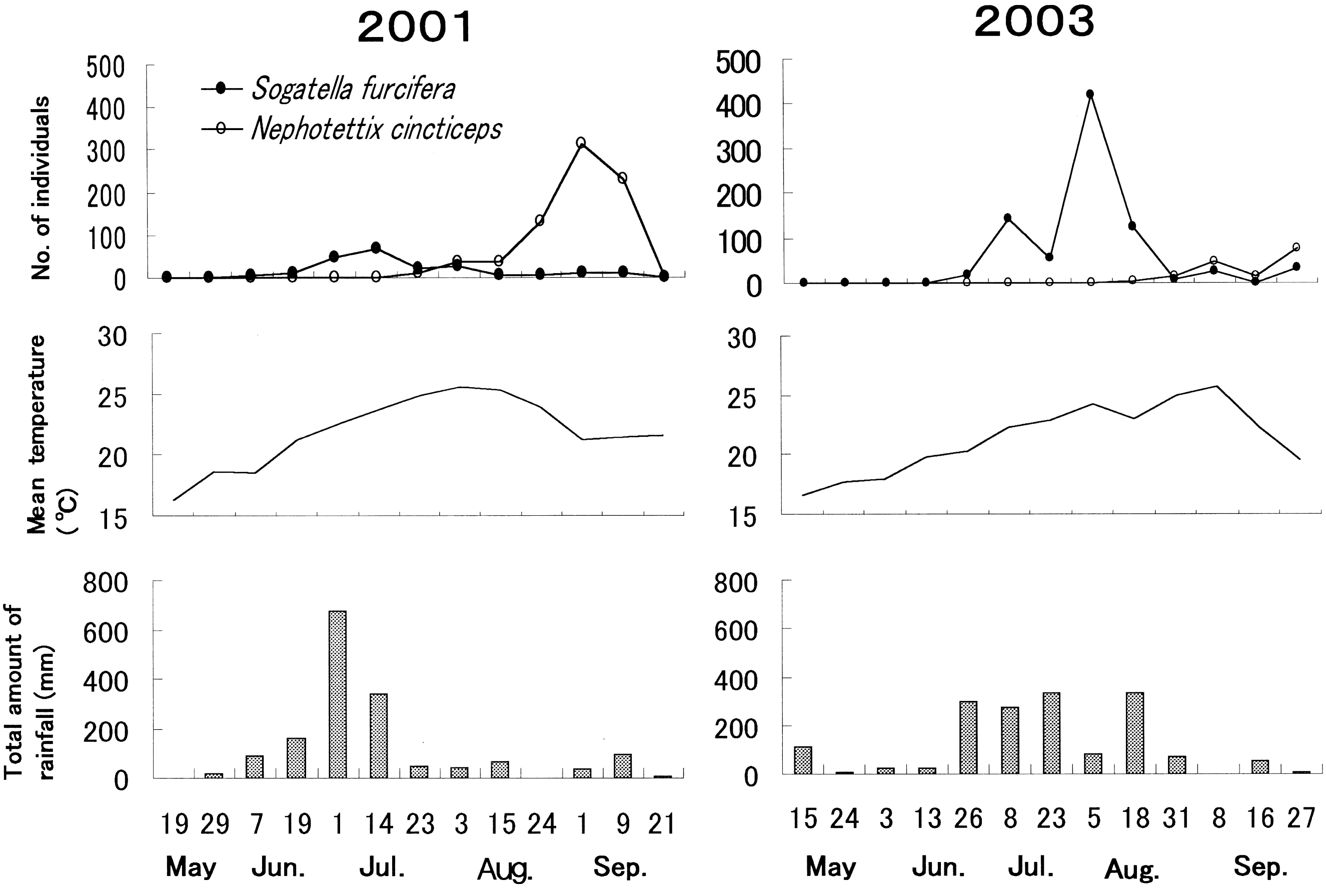

Fig. 1. Seasonal fluctuations in the mean temperature, rainfall, and the total number of *Sogatella furcifera* and *Nephotettix cincticeps* captured by sweeping in five quadrats. Mean temperature and rainfall show the average and the total amount during each survey interval, respectively.

Hydrometra procera (Hydrometridae). The dominant insect pests were *S. furcifera*, *Lyssorhoptrus oryzae* (Curculinidae) and *N. cincticeps*. Other dominant insects were chironomids.

Vertical distributions of spiders and prey insects on rice plants

In 2001, we observed the height on rice plants where *S. furcifera*, *N. cincticeps*, *P. pseudoannulata*, *C. kurilensis* and tetragnathids were located (Figs. 2–6, Appendices 1–5). *Sogatella furcifera* was most abundant at a height of 0–10 cm (Fig. 2). The adults of this species were also observed at upper parts in the early morning or the evening, and sometimes in the daytime (on 15 July). *Nephotettix cincticeps* was found from lower to upper parts of rice plants (Fig. 3). The adults were usually observed at the upper parts in the daytime. The density of this hopper, however, was low, and accordingly, its distribution was not clear.

Pardosa pseudoannulata was located at a height of 0 cm (on the paddy water surface) or 0–5 cm (at the bottom of rice plants) but was not found higher than 10 cm (Fig. 4). However, this spider was sometimes observed at higher parts, 5–10 cm, after mid-July when the rice plants had grown high. *Clubiona kurilensis* was most abundant at a height of 0–10 cm and sometimes found at upper parts (Fig. 5). Thus, *C. kurilensis* may inhabit higher parts than *P. pseudoannulata*. The tetragnathids were observed at upper parts, usually on their webs, in the early morning or the evening, and at lower parts, on the rice plants, in the daytime (Fig. 6).

These results suggest that the vertical distributions of these arthropods change with the time of day or season and differ between species. Then, we statistically analyzed the vertical distributions of them that were obtained from 26 quadrats in 2003. We used the data of *P. pseudoannulata* on 6 June and *S. furcifera*, *P. pseudoannulata* and *C. kurilensis* on 26 July but did not use the data on other days and of *N. cincticeps* and tetragnathids because of low density (<0.5/quadrat). There were no significant differences in locating heights among times of day in *P. pseudoannulata* on 6 June ($P>0.3$, Kruskal-Wallis test) and in three species (*S. furcifera*, *P. pseudoannulata* and *C. kurilensis*) on 26 July ($P>0.5$, 0.1, 0.7, respectively, Kruskal-Wallis test). The location of *P. pseudoannulata* was significantly higher on 26 July than 6 June ($P<0.01$, Wilcoxon rank sum test), similar to the results of 2001. The comparisons between species showed that on 26 July, *P.*

Table 2. Number of spiders cought by the hand collecting method in the paddy field in 2001.

Family, Species	2 June	16 June	3 July	15 July	28 July	13 Aug.	Total
Theridiidae							
Coleosoma octomaculatum	0	0	0	0	0	1	1
Theridion rapulum	0	0	1	0	0	0	1
Theridion subpallens	0	0	2	0	0	0	2
Sp. 1	1	0	0	0	0	2	3
Linyphiidae							
Gnathonarium exiccatum	0	2	0	0	0	0	2
Sp. 1	0	0	0	2	0	0	2
Tetragnathidae							
Leucauge subgemmea	0	0	1	0	0	0	1
Tetragnatha maxillosa	0	0	3	0	0	1	4
Tetragnatha sp. 1 (nymph)	0	0	11	3	20	3	37
Tetragnatha sp. 2 (nymph)	0	0	0	1	0	0	1
Pisauridae							
Cispius orientalis	0	0	0	0	0	1	1
Sp. 1	0	0	4	0	0	3	7
Lycosidae							
Arctosa subamylacea	0	0	1	0	0	0	1
Pardosa laura	2	2	2	0	0	0	6
Pardosa astrigera	1	0	1	0	0	0	2
Pardosa pseudoannulata	4	3	7	3	4	5	26
Gnaphosidae							
Sp. 1	0	0	0	0	0	1	1
Clubionidae							
Clubiona kurilensis	1	1	1	1	2	0	6
Clubiona sp. 1 (nymph)	0	0	0	1	1	1	3
Thomisidae							
Xysticus insulicola	0	0	1	0	2	0	3
Xysticus kurilensis	0	1	0	0	0	0	1
Sp. 1	0	0	1	0	0	0	1
Salticidae							
Harmochirus pullus	0	1	1	0	0	0	2
Marpissa sp.	0	0	0	0	1	0	1
Sp. 1	0	2	0	0	0	1	3
Sp. 2	0	1	0	0	0	0	1
Total	9	13	37	11	30	19	119

Table 3. Number of insects found by a direct counting method in the paddy field in 2001.

Order, Family, Species	2 June	16 June	3 July	15 July	28 July	13 Aug.	Total
Coleoptera							
Curculinidae							
Lissorhoptrus oryzae	46	46	2	1	6	1	102
Echinocnemus squameus	7	6	0	1	0	0	14
Hemiptera							
Delphacidae							
Sogatella furcifera	0	33	8	40	150	73	304
Deltocephalidae							
Nephotettix cincticeps	0	0	0	0	5	17	22
Hydrometridae							
Hydrometra procera	0	13	1	3	1	14	32
Gerridae							
Gerris lacustris latiabdominis	77	77	124	181	40	14	513
Diptera							
Chironomidae	23	100	474	381	39	187	1204
Total	153	275	609	607	241	306	2191

pseudoannulata inhabited significantly lower parts than *S. furcifera* ($P<0.0001$, Wilcoxon rank sum test) and *C. kurilensis* ($P<0.001$, Wilcoxon rank sum test) but there was no significant difference between *S. furcifera* and *C. kurilensis* ($P>0.5$, Wilcoxon rank sum test). These results indicate that *C. kurilensis* and *S. furcifera* locate at a similar height on rice plants but *P. pseudoannulata* inhabits the lower parts.

Spatial distribution pattern of spiders and prey insects

Table 4 shows parameters of spatial distribution of spiders and prey insects. The I_δ values of predators, i.e. *P.*

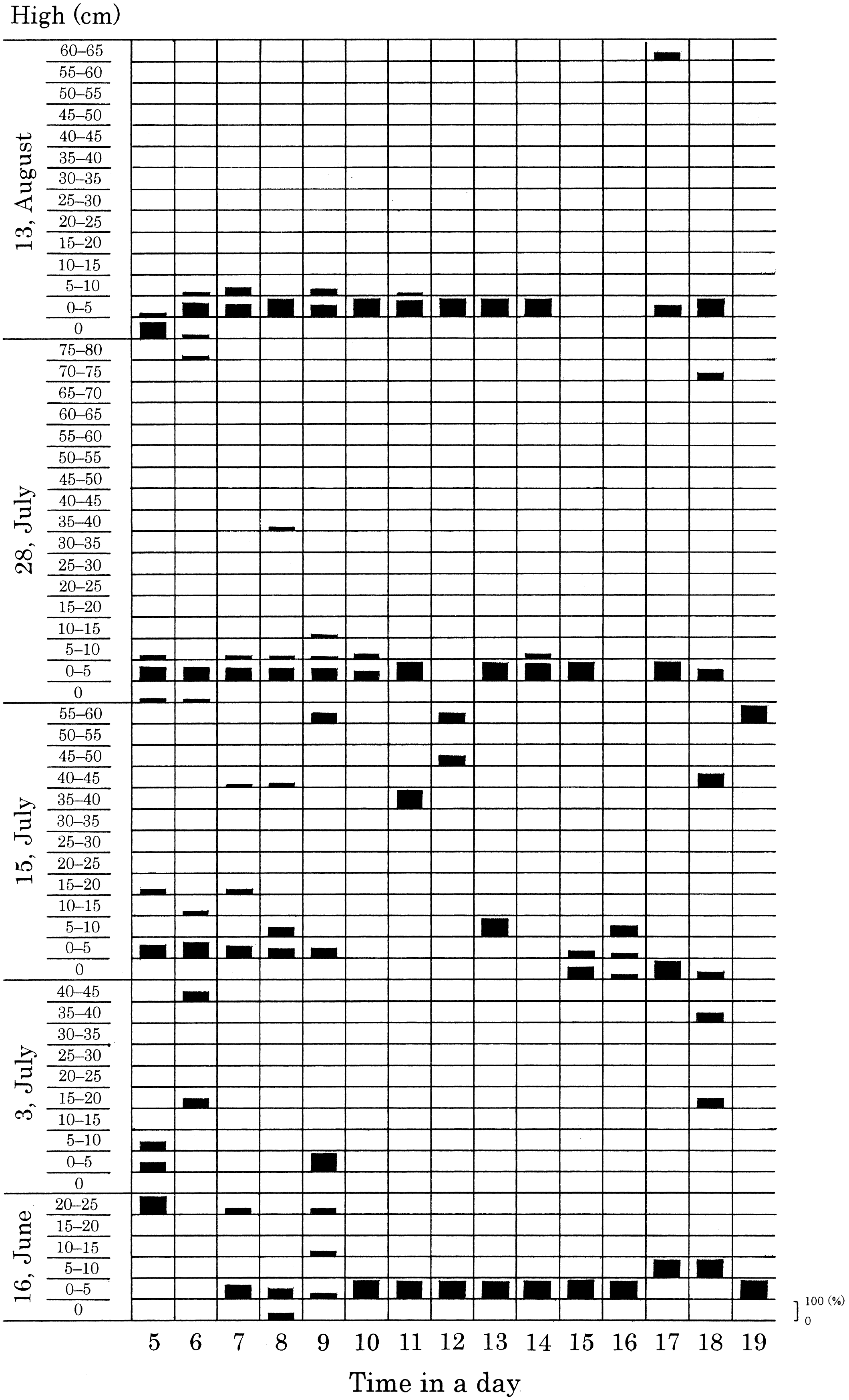

Fig. 2. Daily and seasonal changes in vertical distribution (relative frequency) of *Sogatella furcifera* in 2001.

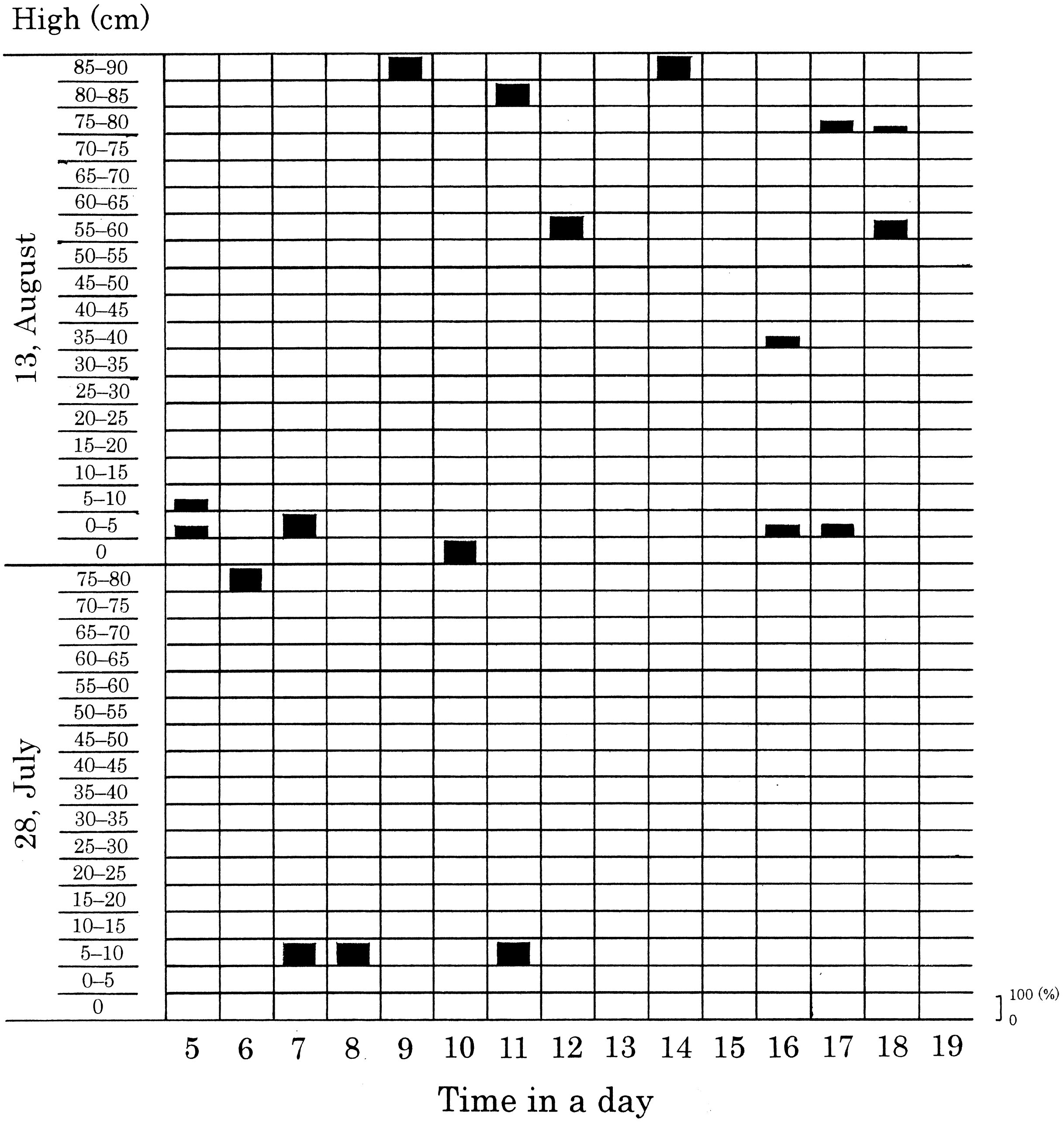

Fig. 3. Daily and seasonal changes in vertical distribution (relative frequency) of *Nephotettix cincticeps* in 2001.

pseudoannulata, *C. kurilensis* and *G. lacustris*, were higher than 1 throughout the survey period, indicating a contagious distribution while the I_δ of all spiders shows contagious (on 6 June) or random distribution (on 21 June and 26 July). The distribution of chironomids and *S. furcifera* was contagious. On the other hand, the I_δ of Diptera (excluding chironomids) were close to 1, indicating a random distribution.

To analyze the degree of overlapping between species, we calculated the ω indices (Iwao 1977) based on their numbers in each quadrat (Table 5). The ω were rather high between all spiders and chironomids on 21 June and between *C. kurilensis* and *S. furcifera* on 26 July. The chironomids and *S. furcifera* were at high density on 21 June and 26 July, respectively (Table 4). Thus, the spiders may aggregate into the sites where the prey insects are abundant. A high value of ω was also recorded between predators, i.e. *P. pseudoannulata* and *G. lacustris* on 26 July.

Discussion

Dominant species of spiders were *Tetragnatha* sp. (certainly *T. maxillosa*), *P. pseudoannulata* and *C. kurilensis* in this paddy field. Murata (1995) reported that tetragnathid spiders were most abundant, followed by thomisids and clubionids in the paddy fields of Aso area. Murata (1995)

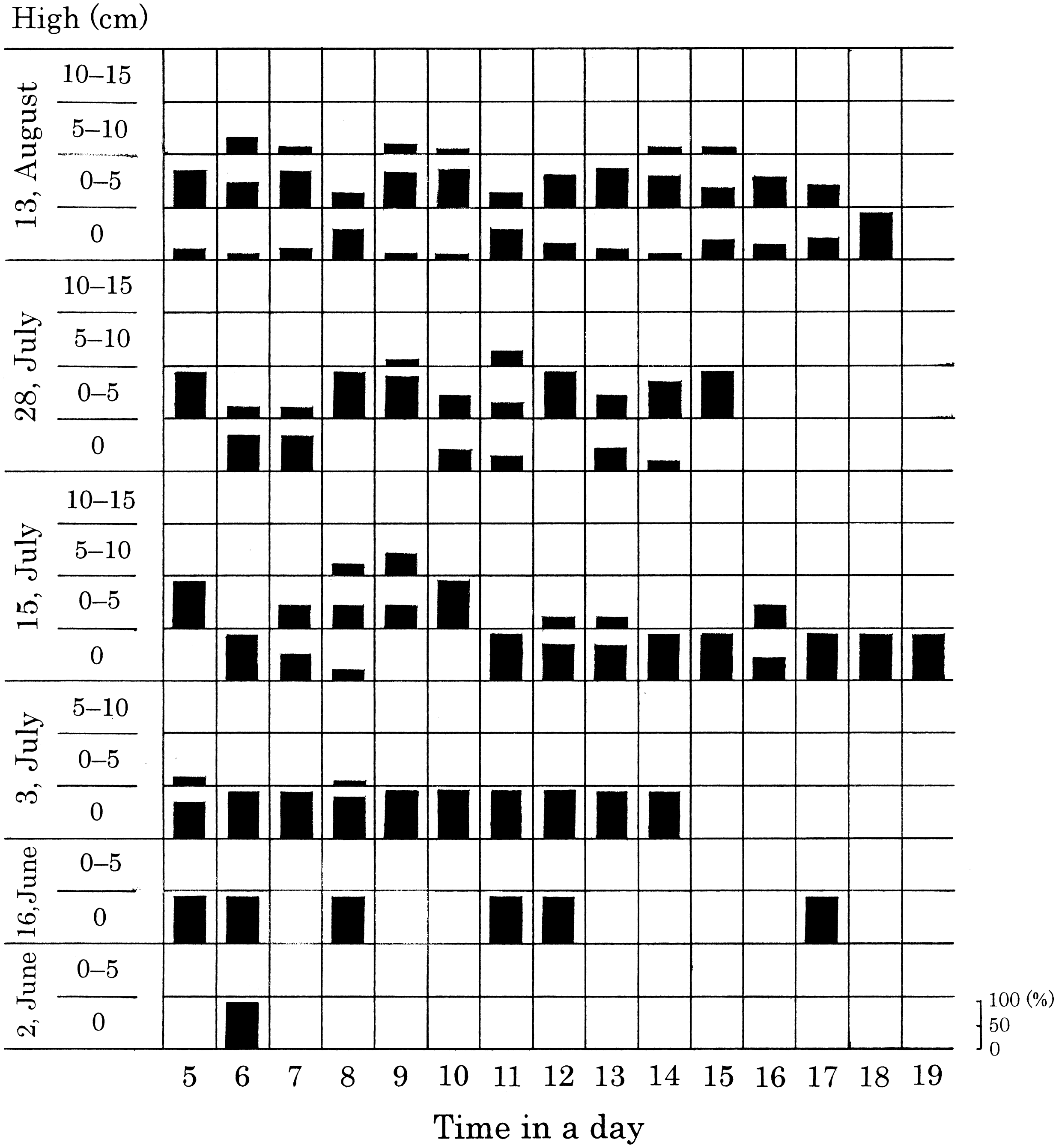

Fig. 4. Daily and seasonal changes in vertical distribution (relative frequency) of *Pardosa pseudoannulata* in 2001.

adopted a sweeping method and probably captured fewer lycosids inhabiting the lower parts of rice plants. We scarcely found dwarf linyphiid spiders, e.g. *Ummeliata insecticeps* and *Gnathonarium exsiccatum*, which were suggested to be important predators of planthoppers (e.g. Kiritani et al. 1972).

The dominant species of rice planthoppers and leafhoppers were *S. furcifera* and *N. cincticeps* but *N. lugens* was not found, similar to the results of Murata & Nohara (1994) that surveyed the insect fauna in this area. The population of *S. furcifera* was at high density in the study period, especially in 2003. Kiritani et al. (1972) showed that *N. cincticeps* and *N. lugens* accounted for 80 % of diets of *P. pseudoannulata*. The diet composition of spiders may depend on the fauna of prey insects. Accordingly, *S. furcifera* is probably one of major prey for spiders in this field.

Chironomids may be another important prey of spiders because they were most abundant among potential prey. Several researchers (Hidaka 1990; Murata 1995; Setlle et al. 1996) suggested that chironomids were of significance as alternative prey when the density of rice insect pests was low. Surakarn & Yano (1999) reported that 14 spider species

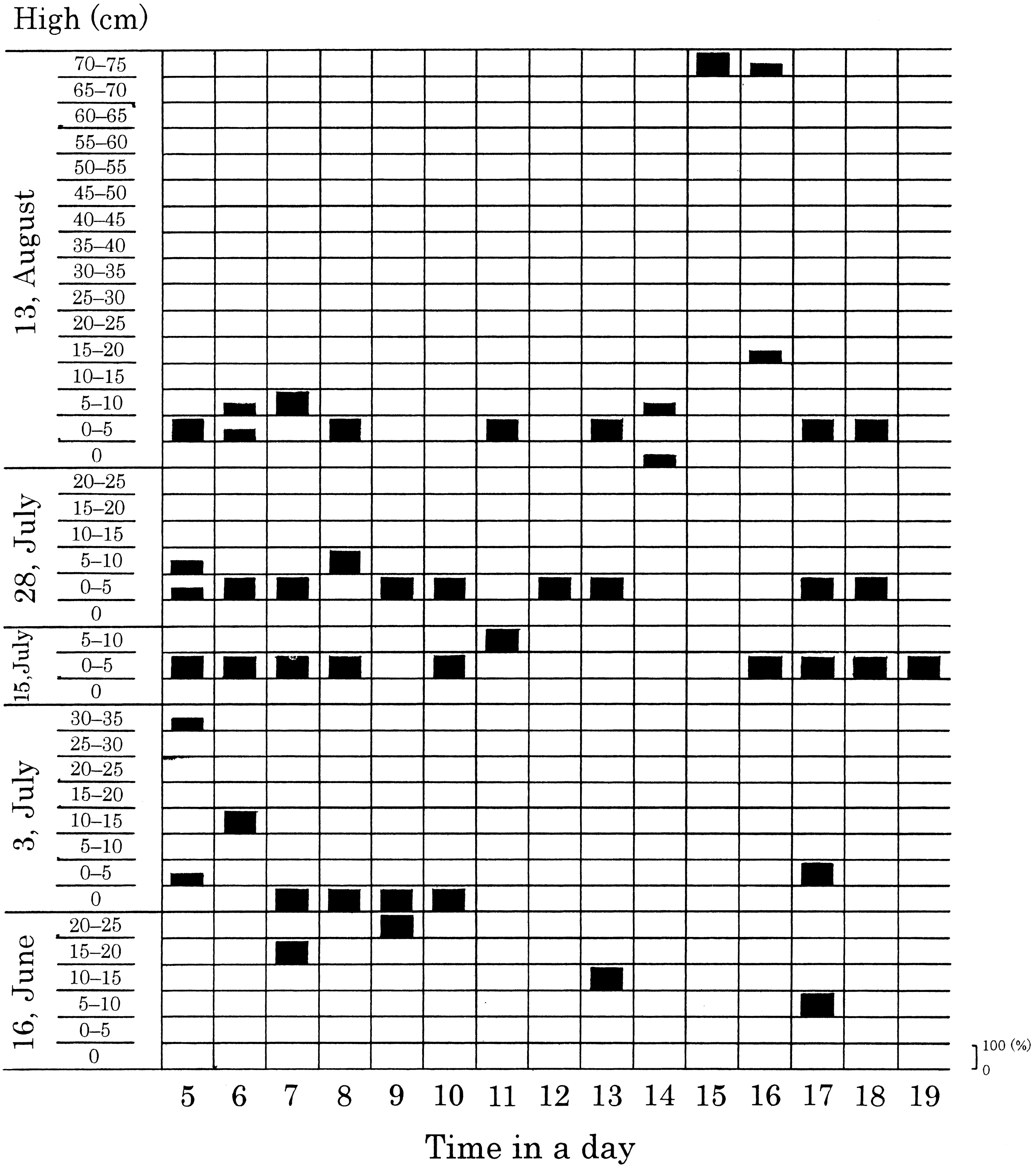

Fig. 5. Daily and seasonal changes in vertical distribution (relative frequency) of *Clubiona kurilensis* in 2001.

including theridiids, *P. pseudoannulata* and clubionids preyed on chironomids.

We observed the vertical distributions of spiders and their prey insects on rice plants. Kuno (1968) analyzed the vertical distributions of four species of the rice leafhoppers and planthoppers and revealed that *N. lugens* aggregated at the lowest parts, near the bottom of rice plants, *N. cincticeps,* on the contrary, was almost uniformly distributed on a whole plant, and *S. furcifera* and *Laodelphax striatellus* inhabited the intermediate parts of plants between the two species. This study showed that *N. cincticeps* was distributed from lower to upper parts of rice plants and *S. furcifera* was abundant at a height of 0–10 cm but also observed at upper parts, showing similar results to Kuno (1968).

The vertical distribution of spiders, however, has not been investigated in detail, though Sasaba et al. (1973) made a brief report on the vertical location of *P. pseudoannulata*. This study showed the vertical distributions of *P. pseudoannulata*, *C. kurilensis* and tetragnathids on rice plants and a difference between them. *Pardosa*

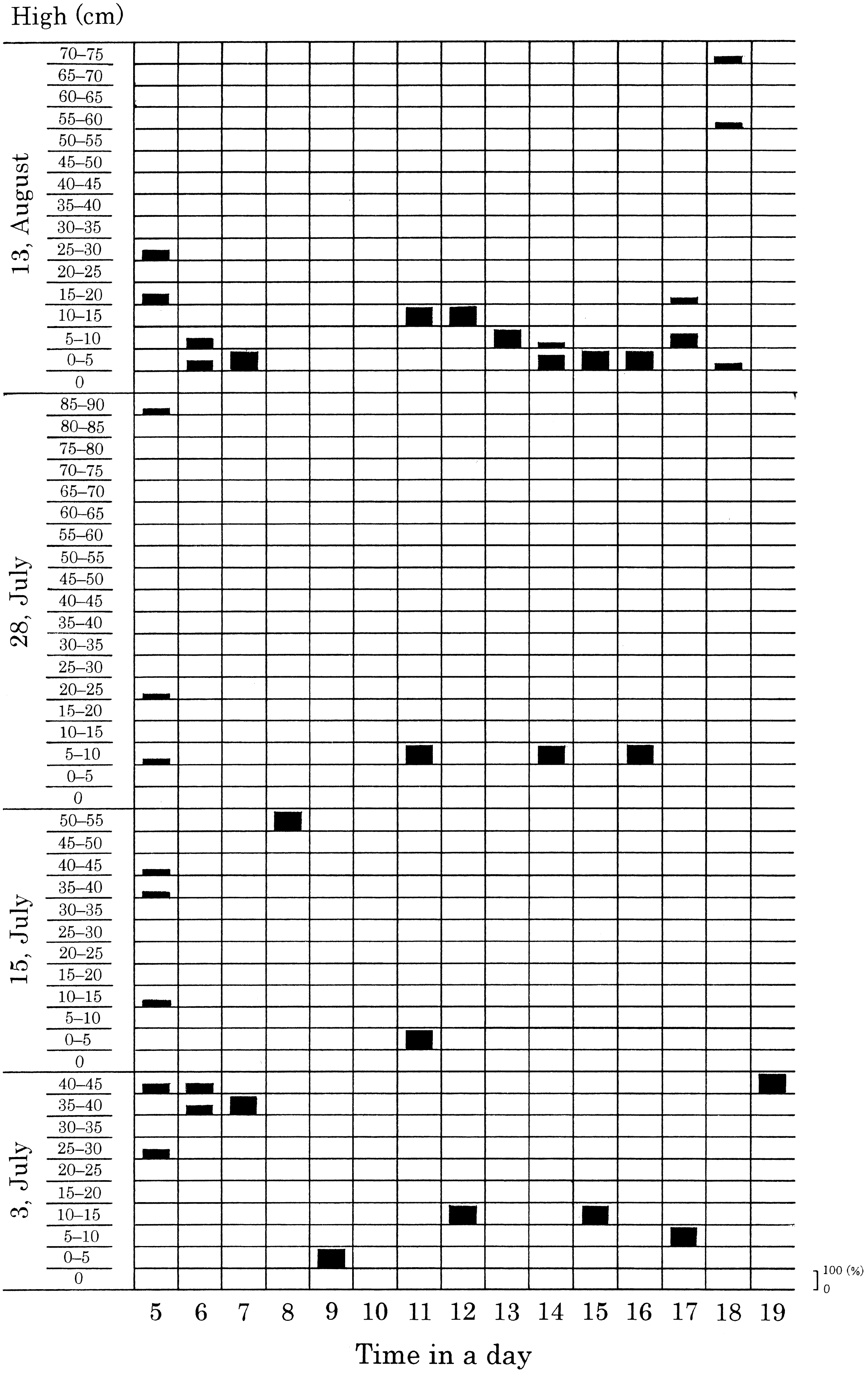

Fig. 6. Daily and seasonal changes in vertical distribution (relative frequency) of Tetragnathidae in 2001.

Table 4. Parameters of distribution of predators and prey insects in the paddy field in 2003.

Species/Taxa	Mean density per m^2			Variance of mean density			I_δ[2]		
	6 June	21 June	26 July	6 June	21 June	26 July	6 June	21 June	26 July
All spiders	1.04	0.57	4.35	1.71	0.7	6.16	1.68*	1.45	1.11
Pardosa pseudoanulata	0.88	0.46	2.19	1.44	0.48	3.44	1.81*	—	1.28*
Clubiona kurilensis	0.00	0.00	1.23	—	—	1.87	—	—	1.46*
Gerris lacustris	2.76	1.82	4.19	4.44	3.71	8.88	1.24*	1.60**	1.28***
Chironomidae	2.92	8.96	4.62	6.49	19.22	81.45	1.44***	1.13***	4.65***
Diptera[1]	0.56	1.21	0.15	0.51	1.43	0.14	0.89	1.18	—
Sogatella furcifera	0.00	0.23	30.81	—	0.25	224.4	—	—	1.21***

[1] Diptera excluding Chironomidae.

[2] I_δ was not calculated on the day when the density was lower than 0.5.

I_δ is significantly different from 1.0 at $P=0.05$ (*), 0.01(**), or 0.001(***) by F-test (Morisita 1959).

Table 5. Indices of interspecies spatial correlation (ω) in 2003.

Species/Taxa	All spiders			*Pardosa pseudoannulata*			*Clubiona kurilensis*			*Gerris lacustris*		
	6 June	21 June	26 July	6 June	21 June	26 July	6 June	21 June	26 July	6 June	21 June	26 July
Chironomidae	0.02	0.327	0.033	0.066	—[1]	0.058	—	—	−0.152	—	—	0.137
Brachycera	−0.296	0.105	—	—	—	—	—	—	—	—	—	—
S. furcifera	—	—	0.201	—	—	−0.043	—	—	0.315	—	—	0.143
C. kurilensis	———	———	———	—	—	0.169	———	———	———	—	—	—
G. lacustris	0.107	−0.158	0.303	0.082	—	0.416	—	—	0.029	———	———	———

[1] Data were not analyzed on the day when the density was lower than 0.5.

pseudoannulata was abundant on the paddy water surface (0 cm high) and at the bottom of rice plants (0–5 cm). But *P. pseudoannulata* was also found at the higher parts, 5–10 cm, when the rice plants had grown high, and their location was significantly higher on 26 July than 6 June. These seasonal changes of locating height may be affected by the distribution of *S. furcifera* that became abundant in late July. In addition, solar radiation or temperature may affect the vertical location since *P. pseudoannulata* was observed at higher parts at night (Sasaba et al. 1973) and in autumn (Tanaka pers. obs.). In the daytime in summer, *P. pseudoannulata* might be located at lower parts to avoid solar radiation that may heat the spider body to an unfavorable temperature. If this is true, the canopy of rice plants that has grown large can shade the plants under the canopy and the spiders may be located rather higher parts. On the other hand, *C. kurilensis* was most abundant at a height of 0–10 cm and also found at the upper parts of rice plants. These results suggest that *C. kurilensis* inhabits the plants closer to *S. furcifera* than *P. pseudoannulata*. In fact, the statistical analyses showed that *P. pseudoannulata* was located at a significantly lower height than *C. kurilensis* and *S. furcifera*, but there was no difference in height between *C. kurilensis* and *S. furcifera*. The observed low height of *P. pseudoannulata* is similar to that of *N. lugens* though *N. lugens* were not found in this study field. In addition, it may be relevant to the prey capture behaviors that *P. pseudoannulata* attacks a prey falling on the water surface (Kiritani et al. 1972).

Clubiona kurilensis was observed at the upper parts of rice plants in the early morning and the evening. This observation suggests that *C. kurilensis* actively forage prey in these periods. On the other hand, *P. pseudoannulata* was consistently located at the lower parts and did not exhibit an apparent pattern of daily activity. Murata (1999) showed that *P. pseudoannulata* was active during 8:00–10:00 and 17:00–18:00 in winter in the Iriomote Island, Okinawa. Thus, the daily activity of *P. pseudoannulata* may vary depending on environmental factors. The tetragnathids exhibited a daily activity pattern; they were observed, in the early morning and the evening, on their webs that were constructed at upper parts of rice plants. They may forage primarily at night.

We analyzed the degree of spatial overlapping between spiders and their prey insects by using the Iwao's (1977) ω index and revealed positive correlations between some species or taxons, i.e. spiders and chironomids on 21 June 2003 and *C. kurilensis* and *S. furcifera* on 26 July 2003. These results support the idea that the chironomids may be an important prey for spiders and suggest that *C. kurilensis* depends on *S. furcifera* for prey. The positive correlations were detected when the corresponding prey were most abundant. Thus, *C. kurilensis* may adopt the foraging strategy that it switches the prey species depending on the prey density and aggregate into the sites affording high prey density. A positive correlation was also detected between predators, i.e. *P. pseudoannulata* and the water strider *G. lacustris latiabdominis* on 26 July 2003. A reason for this correlation is not clear and should be further investigated.

We showed that, in this paddy field, tetragnathids, *P. pseudoannulata* and *C. kurilensis* were dominant among spiders and *S. furcifera*, *N. cincticeps* and chironomids were abundant among their prey insects. These spiders were different in the vertical locations on rice plants and the prey capture behaviors, and therefore, may have different compositions of prey species. *Clubiona kurilensis* and *S. furcifera* had a positive correlation of spatial distribution, including horizontal and vertical distribution, within a paddy field.

Thus, this spider may be an effective predator of *S. furcifera* even though it has not been regarded as an important predator of rice planthoppers. Further researches are needed for evaluating the predatory effect of *C. kurilensis* and spider assemblage on the population of rice pests. In addition, dominant species of spiders and insects inhabiting paddies vary from region to region. Hence, it is required to study their biology in each region and to utilize the spiders as biological control agents as well as other natural enemies by considering their characteristics.

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Appendix 1. Total number of *Sogatella furcifera* found in 3 quadrats at each survey time in 2001.

Date	Time in a day														
	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
16 Jun.	1	0	6	8	3	4	1	1	1	1	1	1	1	1	1
3 Jul.	2	2	0	0	2	0	0	0	0	0	0	0	0	2	0
15 Jul.	3	5	9	5	2	0	1	2	1	0	3	4	2	3	1
28 Jul.	46	28	14	20	10	6	6	0	4	5	3	0	3	5	0
13 Aug.	21	14	7	1	4	1	12	1	0	3	2	0	3	4	0

On 2 June, no individual was found.

Appendix 2. Total number of *Nephotettix cincticeps* found in 3 quadrats at each survey time in 2001.

Date	Time in a day														
	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
28 Jul.	0	1	1	2	0	0	1	0	0	0	0	0	0	0	0
13 Aug.	2	0	2	0	1	1	2	1	0	1	0	2	2	4	0

On the other survey days, no individual was found.

Appendix 3. Total number of *Pardosa pseudoannulata* found in 3 quadrats at each survey time in 2001.

Date	Time in a day														
	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
2 Jun.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
16 Jun.	1	2	0	1	0	0	1	1	0	0	0	1	0	0	0
3 Jul.	3	2	2	4	5	1	1	1	1	1	0	0	0	0	0
15 Jul.	2	1	4	4	4	2	2	3	3	2	1	4	3	1	2
28 Jul.	5	3	6	7	4	2	3	2	2	3	1	0	0	0	0
13 Aug.	15	16	10	8	18	13	8	10	10	9	7	8	4	3	0

Appendix 4. Total number of *Clubiona kurilensis* found in 3 quadrats at each survey time in 2001.

Date	Time in a day														
	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
16 Jun.	0	0	1	0	1	0	0	0	2	0	0	0	1	0	0
3 Jul.	2	1	2	1	2	1	0	0	0	0	0	0	1	0	0
15 Jul.	1	1	1	1	0	1	1	0	0	0	0	1	1	1	1
28 Jul.	2	2	3	1	2	1	0	1	1	0	0	0	1	1	0
13 Aug.	2	2	1	2	0	0	2	0	1	2	2	2	1	1	0

On 2 June, no individual was found.

Appendix 5. Total number of Tetragnathidae found in 3 quadrats at each survey time in 2001.

Date	Time in a day														
	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
3 Jul.	2	2	1	0	1	0	0	1	0	0	2	0	1	0	1
15 Jul.	3	0	0	1	0	0	1	0	0	0	0	0	0	0	0
28 Jul.	3	0	0	0	0	0	1	0	0	1	0	1	0	0	0
13 Aug.	2	2	1	0	0	0	1	1	4	3	1	1	3	3	0

On the other survey days, no individual was found.